PATENT

IN THE UNITED STATES PATENT AND TRADE MARK OFFICE

Applicant	: Murray et al	Examiner	: L. Tran
Serial No.	: 10/663437	Group Art Unit	: 1725
Filed	: September 16, 2003	Docket	: U 014758-5
Title	: MAGNESIUM PRESSURE CASTING		

DECLARATION

1. I, Dr Stephen P Midson, of 1353 South Gaylord Street, Denver, CO 80210, United States of America, am the President of The Midson Group, Inc., of that address. As detailed by my company at its website <www.themidsongroup.com>, I am an internationally recognised expert in semi-solid processing, die casting, foundry technology, metal shaping and metallurgical evaluations. I have a B. Metallurgy Degree, and PhD in metallurgical engineering, both from Sheffield University, in Sheffield, England, and more than 20 years casting and metallurgical experience. I have authored more than 30 technical papers, and received awards from the society of Automotive Engineers, The American Foundry Society, and Sheffield University.

2. I have been requested to provide this declaration as an independent expert. The request was made by an Australian Patent Attorney acting for the assignee for US

application 10/663437. While my charges for time in preparing for this declaration are being paid, I am a completely independent expert in this matter.

3. I have been provided with:

(a) a copy of US application 10/663437 (with the patent claims 50 to 67);

(b) a copy of US patent 6634412 to Murray et al, granted on a parent application for 10/663437;

(c) a copy of a US Patent Examiner's report indicated as mailed on August 22, 2005 on application 10/663437; and

(d) a copy of US patent 5685357 in the name of Kato et al, assigned to The Japan Steel Works, Ltd (JSW).

I have been asked to advise in relation to the relevance asserted in the Examiner's report of Kato et al to the invention of claims 50 to 67 of US 10/663437.

4. Prior to being asked to provide this declaration, I was aware of the machinery of JSW as embodied in Kato. I also was aware of the work of the assignee for US 6634412 and application 10/663437 as embodied in a process known as ATM (an abbreviation for Advanced Thixotropic Metallurgy). Particularly in view of this prior knowledge, I was astounded by the relevance incorrectly attributed to Kato in relation to the ATM invention of claims 50 to 67. I consider Kato clearly does not have this relevance. This is because the reasoning of the Examiner's report in relation to Kato:

(a) is not consistent with the prior art over which Kato seeks to distinguish,

(b) is not consistent with the solution proposed by Kato, and

(c) is contrary to what Kato discloses to a person skilled in the art of semi-solid processing.

Indeed, as a summary of matters on which I comment in later paragraphs, I consider that:

(i) Kato does not disclose a controlled expansion region;

(ii) Kato does not disclose or suggest a system or machine by which alloy can be changed <u>from</u> a molten state <u>to</u> a semi-solid state;

(iii) Kato does not disclose any region in which, even if capable of a flow velocity of between 140 to 165 m/s, this would be followed by a <u>reduction from that</u> flow velocity necessary in the invention of claims 50 to 67 of application 10/663437 for causing molten alloy to change <u>from</u> a molten state <u>to</u> a semi-solid state;

(iv) Kato discloses apparatus which is not capable of changing alloy from a molten state to a semi-solid state;

(v) Kato does not disclose or suggest the invention of claims 50 to 67 of application 10/663437.

5. Kato is concerned with injection molding of shaped metal parts. The underlying technology of Thixomolding over which Kato provides an advance has evolved over the last 30 years, and is well known, particularly in relation to the casting of magnesium alloys. Thixomolding technology is covered by many patents and is controlled by Thixomat, Inc. (see <www.thixomat.us>). The machines used in Thixomolding are made by JSW (the assignee of Kato) and by Husky Injection Molding Systems Ltd of Canada. Thixomolding involves the injection molding of a thixotropic semi-solid alloy,

using a machine which is similar to a thermoplastics injection molding machine. In Thixomolding, cold alloy chips are fed to a barrel containing a helical screw and the alloy is heated and partially melted under shear imparted by rotation of the screw as the alloy advances to a nozzle at the end of the barrel. Molding is achieved by axially moving the screw to force the semi-solid alloy from the barrel, through the nozzle and into a cavity of a permanent mold. Kato departs from this standard form of Thixomolding by progressively heating the alloy such that it is fully molten at the end of the barrel, whereby molten alloy is forced through the nozzle and into the mold cavity instead of semi-solid alloy.

6. Central to the erroneous reasoning on which Kato incorrectly is said to be relevant to the ATM invention of claims 50 to 67 is the part (45) of the machine of Figure 1(A) of Kato. Part (45) is mentioned only twice in Kato (at column 6, lines 6 and 48). In each case, the part is identified solely as a "sprue". In the context of Thixomolding and Kato, a sprue is an opening through which alloy is injected into a mold, and this is completely consistent with the machinery produced by both JSW and Husky for injection molding. In contrast, the erroneous reasoning refers to part (45) as "a controlled expansion region (45)" and this is despite the facts that:

(i) the simple reference in Kato to "sprue 45" does not provide any suggestion of a controlled expansion region;

(ii) there is no other passage of Kato which provides any suggestion that part (45) is (or could be) a controlled expansion region; and

(iii) the reasoning does not accord with the clear meaning of "sprue" to a person skilled in the art.

7. Figure 1(A) is an illustration of the overall machine used by Kato. Indeed, Figure 1(A) is a somewhat simplified, schematic illustration, with sprue 45 in particular being considerably simplified. The sprue region in a machine of that type is quite complex and made up of precision made components. Indeed, it often is the case that molds for injection molding incorporate off-the-shelf components purchased by a mold-maker from specialist manufacturers such as D-M-E Company (see <www.dme.net>). What Kato in fact shows by "sprue 45" is merely the outer envelope of the sprue. Kato omits the detail of components within the envelope which are too small to be capable of clear illustration at the scale of Figure 1(A) of Kato.

8. In the categorization in Examiner's report of sprue 45 as a controlled expansion region, it appears implicit that sprue 45 is assumed to have a circular cross-section which increases in cross-section and diameter, in a direction away from nozzle 3, up to the parting line between mold parts 43 and 44. There is no basis for this even if what is shown by Kato is incorrectly taken as fully characterising a sprue. Figure 1(A) is in two-dimensions, and there is no information for categorically assuming a three-dimensional form for sprue 45. Also, a region 45 of circular cross-section which increases in a direction away from nozzle 3 would not function as an effective sprue. However, these matters are not relevant given what a person skilled in the art would know to be disclosed by Kato by the simple reference to "sprue 45".

9. A person skilled in the art would understand "sprue 45" as consisting of a sprue bushing and a sprue post, sometimes referred to as a sprue spreader. The sprue bush

defines a bore which increases in diameter in the metal flow direction, and the bore of the sprue bush is all that is shown by Kato in mold part 44. The sprue post has a complementary external taper so as to be received in the bore of the sprue bush. The sprue post is not shown in Kato. However the sprue post would be mounted in the hollow shown in mold part 43 at the end of the sprue bush bore. The taper of the bore of the sprue bush and also the taper of the sprue post is to prevent a back draft condition which would prevent removal of a casting. The sprue post substantially fills the bore of the sprue bush, apart from a flow path constriction defined between the sprue bush and the sprue insert. Thus, what is referred to as the envelope identified as 45 in Kato is not a hollow expanding bore, but rather a bore substantially fully occupied by a solid insert comprising the sprue post. Thus, there is no expansion possible in the sprue 45 of Kato.

10. My comments set out in paragraph 9 can be illustrated by Attachment A consisting of pages 287, 288 and 290 from ASM HANDBOOK Vol 15, CASTING, ASM-The Materials Information Society, USA, 1998. These pages relate to pressure die casting, but injection molding as in Kato and pressure die casting are the same in this regard, and differ only in respect of the mode of delivery of alloy to the sprue system of a mold. Figure 1 at page 287 is a schematic illustration of a die casting machine in which the sprue is illustrated in essentially the same manner as in Kato. It is necessary to refer to the more realistic illustration of Figure 3 at page 288 for a more complete understanding of that to which Figure 1 relates. Thus, in Figure 3, the mold parts designated as an ejection die half and a cover die half have been rotated relative to each other for ease of illustration of the detail of their faces which meet at the parting

plane. The sprue bushing shown in the cover half has a tapered bore which increases in circular cross-section from right to left as shown, in the direction of alloy flow therethrough. The sprue spreader of the ejection half has a similar taper and occupies substantially the full volume of the bore of the sprue bushing. In the arrangement of Figure 3, metal solidifies in the casting cavity, back along the runner shown in the ejector die half and back between the sprue bushing and the sprue spreader. Thus a resultant casting, as ejected, has attached to it metal solidified in the runner and in the sprue. The metal solidified in the sprue may be in the form of a thin walled, hollow cone as shown in broken outline in the schematics shown in the bottom right-hand corner of Figure 5 at page 290. However, in some instances, the sprue spreader is a neat fit in the bore of the sprue bushing, with alloy flow through the sprue passing along a sprue runner cut in the sprue bushing, as represented in solid outline in the bottom right-hand corner of Figure 5. In the latter case, metal solidified in the sprue is in the form of a bar corresponding to the sprue runner.

11. To elaborate on the matters of paragraph 10, the cone shown in broken outline in the lower right corner of Figure 5 of Attachment A can be understood as representing the tapered inner surface of the sprue bushing. Thus, it corresponds to the inner surface of the sprue bushing shown in the cover die half of Figure 3 of Attachment A, while it also corresponds to the sprue 45 of Kato et al insofar as sprue 45 is schematically shown. However, both the cone shown in broken line in Figure 5 of Attachment A and sprue 45 of Kato fail to include the necessary sprue post received within and substantially filling the sprue bush. In this regard, sprue 45 of Kato is even more schematic and simplified than the hot chamber machine (b) shown in the lower left

corner of Figure 5 of Attachment A. In that machine A, the conical form of the inner surface of the sprue bush is evident, as also is the conical sprue post or spreader shown within the sprue bush. What is not apparent from the detail of machine (b) of Figure 5 is whether the two lines depicting alloy flow through the sprue are in separate sprue runners, or comprise diametrically opposite sides of a sectioned cone (see Attachment B) of alloy flow through the sprue. However, in neither case is there a basis for assuming a reduction in alloy flow velocity through the sprue, as it is normal practice to progressively increase alloy flow velocity to a maximum at the gate to the die cavity. View (b) of Attachment B shows alloy that solidified in a sprue and in downstream runners of a feed system in which the opposed surfaces of the sprue bushing and the sprue post or spreader were radially spaced from each other. Thus, the sprue metal has a conical outer surface which solidified against the sprue bushing and a conical inner surface which solidified against the outer surface of the sprue post or spreader. The sprue metal thus is hollow, as is evident from the open end seen in view (b) of Attachment B, with the hollow corresponding to the form of the sprue post present during casting. It is practice to have alloy flow velocity progressively increase in the flow direction, and not to decrease, which necessitates the hollow sprue metal decreasing in wall thickness to offset the increasing outer diameter.

12. Thus, it is clear that Kato discloses a flow system, but <u>not</u> one which includes "a controlled expansion region (45) ... of a form which enables flow therein to spread laterally, whereby ..." there is "the reduction in flow in the expansion region by which the state of the alloy is changed from a molten state in the runner to a semi-solid state". In relation to this deficiency in the disclosure of Kato, it is clear that:

(i) Kato does not disclose a reduction in flow velocity at any stage,

(ii) Kato does not disclose a change of state from the molten state to a semi-solid state,

(iii) a change from molten to semi-solid is contrary to what Kato teaches as necessary, namely, the flow of molten alloy into the die cavity and hence specific avoidance of semi-solid flow into the die cavity.

Thus, the relevance attributed to Kato in relation to claims 50 to 67 is astounding in that it is:

(i) contrary to the prior art (Thixoforming) over which Kato seeks to provide an improvement,

(ii) contrary to the improvement Kato proposes, and

(iii) entirely without basis at all in the disclosure of Kato.

A person skilled in the art would reject the relevance attributed to Kato, and the reasoning which underlies this. The reasoning is based on an incorrect interpretation as to what "sprue 45" of Kato comprises.

13. The system (of Kato) is said to be capable of an alloy flow velocity between 140 to 165 metres per second. Even if this was correct, it would not correct the matters I have summarized in paragraph 12. However, it also lacks relevance for other reasons. In both Thixomolding and die casting, the alloy flow path progressively decreases in effective cross-section, such that the flow velocity progressively increases through to a maximum flow velocity at the in-gate (ie the opening to the die cavity). Thus, in the unlikely event that an extremely high flow velocity approaching 140 to 165 metres per second could be attained, this would only be at the in-gate. However, it is not sufficient

simply to attain a velocity of that order since, in addition to such high velocity being very prejudicial in causing severe wear of costly mold components, the high velocity will not itself result in a change of state of the alloy. The claims 50 to 67 of application 10/663437 clearly necessitate an arrangement which satisfied the successive conditions of:

(a) an extremely high runner flow velocity, and

(b) a subsequent reduction in flow velocity in an expansion region,

in order to change alloy from a molten state to a semi-solid state. Condition (b) must follow after condition (a) in order to satisfy those claims, and this is not shown or suggested by Kato. A sprue 45 as in Kato, when properly understood, will not enable these conditions to be satisfied, while that change of state is contrary to what Kato expressly is directed to achieving.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge and that wilful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such wilful false statements may jeopardise the validity of this application or any patent issuing thereon.

Stephen Midson

(Stephen P MIDSON)

February 8 , 2006

Dated

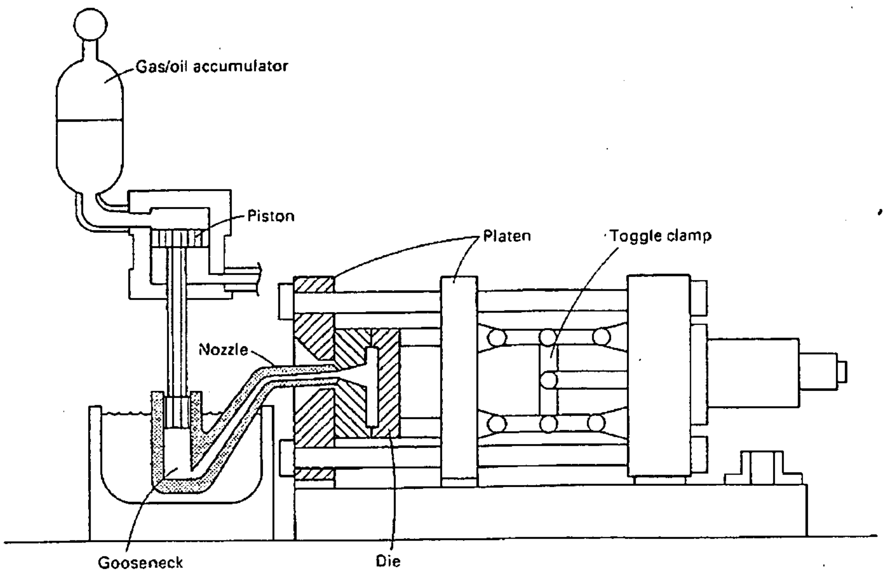


Fig. 1 Schematic showing the principal components of a hot chamber die casting machine

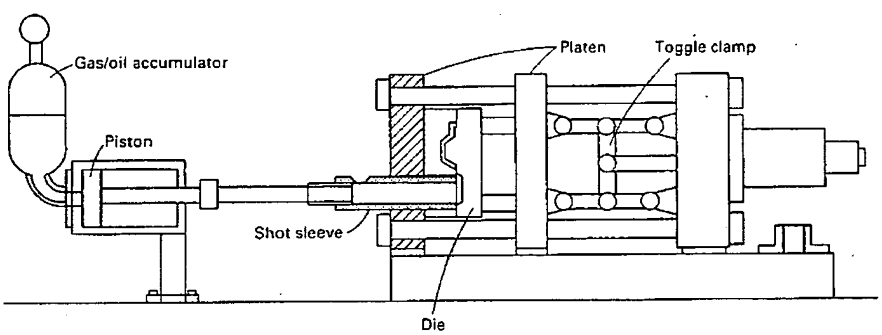


Fig. 2 Schematic showing the principal components of a cold chamber die casting machine

high-speed nature of the process allows the filling of thin-wall complex shapes at high rates (of the order of 100 parts per hour per cavity). This capability places additional demands on the casting designer because traditional feeding of solidification shrinkage is almost impossible. The inability to feed in the traditional sense demands that machining stock be kept to a minimum; high-integrity surfaces should be preserved.

A factor in cost is the parting line topology. The parting line is the line on the casting generated by the separation between one die member and another. The simplest and lowest-cost die has a parting line in one plane. Casting design should be adjusted if possible to provide flat parting lines. Draft is required on the die casting walls perpendicular to the parting line or in the direction of die motion (Fig. 4). An important characteristic of good design is uniform wall thickness, which is necessary for obtaining equal solidification times throughout the casting. Die castings have wall thicknesses of about 0.64 to 3.81 mm (0.025 to 0.150 in.), depending on casting shape and size (Table 2). Bosses, ribs, and filleted corners always cause local increases in section size. In particular, bosses that must be machined require consideration of the entire product-manufacturing cycle. The machinist will find it easier to drill into a solid boss; cored bosses may require floating drill heads in order to align the drill with the cast tapered hole that preserves the high-integrity skin of the casting.

Cores and slides provide side motions for undercuts. A core body is generally round and buried within the cover or ejector die. A slide body has a rectangular or trapezoidal shape and crosses the parting line of the die. As with the cover and ejector dies, the impression steel is often separate from the holder steel. Cores and slides are actuated by various methods, including hydraulic cylinders, rack and pinion, and angle pins. Innovative die design permits radial die motion at a price of die expense. There are die casting processes that use complex-shaped disposable cores similar to those in other gravity casting processes. Cores and slides provide the casting designer with tremendous flexibility at the expense of an increase in die complexity. A standard set of cores—fixed core pins for small holes that are screwed in, or bolted-in inserts—can be used to reduce die construction cost and to permit rapid replacement.

Loose Pieces and Inserts. In certain cases, a reentrant shape needs to be cast into the part where there is no space for core/slide mechanisms. In such a case, the die designer can use a loose piece. A loose piece is placed in the die before each shot is made. It is then ejected from the die with the casting and separated manually or by fixture. Although it provides design flexibility, the load/unload sequence required for loose pieces slows the process, thus increasing cost.

Similarly, the die casting process can allow the part designer great flexibility in local material properties by the use of cast-in inserts of other materials, such as steel, iron, brass, and ceramics. The bond between insert and casting is physical, not chemical, in nature. Therefore, the insert should be clean and preheated. The insert should be designed to prevent pullout or rotation under working loads; knurling, grooves, hexagons, or flats are commonly used for this purpose. Proper support of hollow inserts will prevent crushing of the insert under the high metal injection pressure. The wall thickness of the casting surrounding an insert should be no less than 2.0 mm (0.080 in.) to prevent cracking by shrinkage, hot tearing, and excessive residual stresses.

Trimming. The die cast part is ejected from the die with a variety of appendages (gates, overflows, vents, flash, and robot grasping lugs) that must then be removed. This secondary process is called trimming. Although trimming can be done manually, the high production rates characteristic of die casting demand automation. Trim presses are used to remove the excess material. Castings are often trimmed immediately after the casting process because their higher temperature reduces the strength of the metal.

Trimming conditions directly influence the design of the part and the die casting process, especially gating and parting line definition. Trimming is facilitated by flat parting lines. The relatively rough edge that results from trimming may be acceptable and is often left as is. In some cases, this rough edge is not acceptable and must be removed by machining or grinding. The direction of flash must be such that the edge is machinable.

Dimensional variation is determined by die design, the accuracy of die construction, and process variation. The most accurate

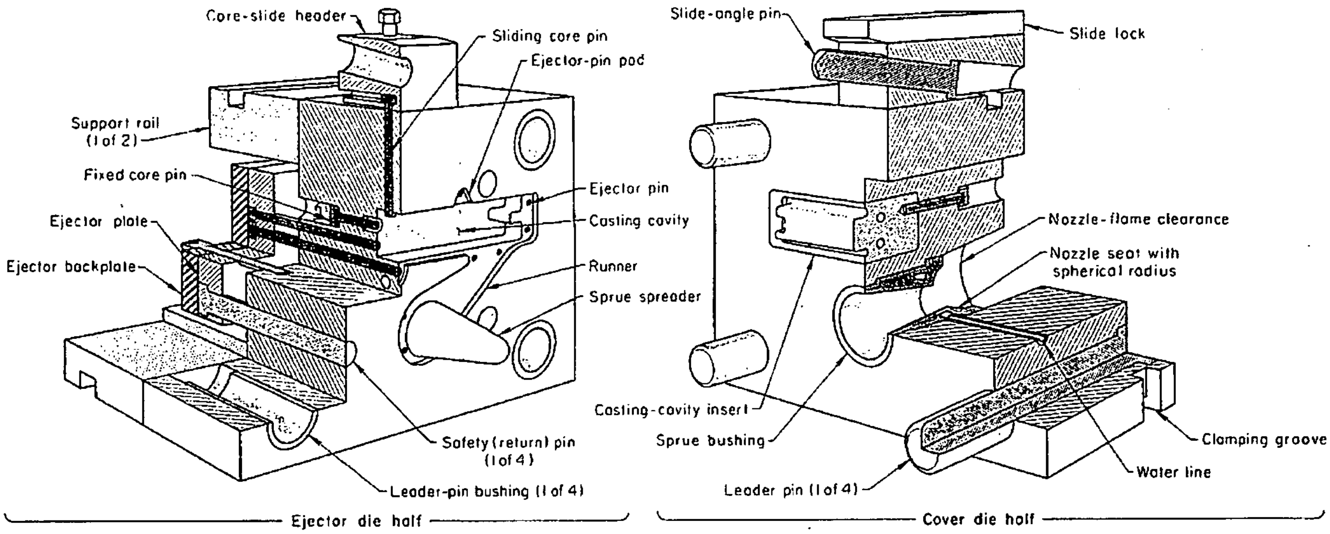


Fig. 3 Components of a single-cavity die casting die for use in a hot chamber machine

dies are those machined using computer numerical control methods. Close control of alloy composition, temperature casting, time, and injection pressure will lead to more consistent casting dimensions. The minimum variation in dimensions is required for those features contained entirely within one die half. Table 3 lists the tolerances on linear dimensions recommended by the American Die Casting Institute (ADCI); Tables 4 and 5 list additional tolerances recommended by ADCI. Therefore, machining locators should ideally be placed in the same die half. Tolerances are a function of casting size and projected area. Features across parting lines have added variation because of the accuracy of repeated die closing. Die temperature, machine hydraulic pressures, and die cleanliness are the principal factors to be controlled. Finally, further dimensional variation occurs if the feature is in a moving die member such as a slide or core.

In summary, a cost-effective die casting demands proper attention to the dimensional variation of the process. Inattention to dimensional factors will lead to an inability to provide consistent products within economic process conditions. The product designer and the die caster must therefore initiate a dialog early in the product cycle.

Gating

The first step in the process sequence is the supply of the molten alloy to the casting machine and its injection into the die. The fluid flow is divided into three considerations: metal injection, air venting, and feeding of shrinkage.

Metal Injection

The distinguishing characteristic of the die casting process is the use of high-velocity injection. The short fill time (of the order of milliseconds) allows the liquid metal to move a great distance despite a high rate of heat loss. The elements of a typical metal gating system are illustrated in Fig. 5.

Proper process performance depends on the delivery of molten metal with high quality as defined by temperature, composition, and cleanliness (gas content and suspended solids). The molten alloy is prepared from either primary ingot or secondary alloys. A melting furnace is used to provide the proper temperature and to allow time for chemistry adjustment and degassing. The alloy is often filtered during transfer to a holding furnace at the casting machine.

The Injection Chamber. Three components make up the injection chambers used for the three types of die casting: the shot sleeve, the gooseneck, and the nozzle (Fig. 1, 2). The cold chamber shot sleeve (Fig. 2) is unique. Initially, it is only partially filled to prevent splashing and to allow for metering error, and it must be filled by slow piston movement to avoid wave formation and air entrainment. Then, for all three chambers, the hydraulic piston rapidly accelerates the molten metal to the desired velocity for injection (Fig. 6). Most die casting machines provide the ability to control the piston acceleration in a linear fashion. Parabolic velocity curves are also available on some controls. This phase of injection can be accomplished in several steps. The third phase of injection is activated as the cavity is close to being filled. This intensification phase draws on an accumulator of high-pressure hydraulic fluid or multiplies pressure using conventional

Table 2 Minimum section thicknesses for die castings

Surface area of casting(a) cm²	in.²	Minimum section thickness for: Tin, lead, and zinc alloys mm	in.	Aluminum and magnesium alloys mm	in.	Copper alloys mm	in.
Up to 25	Up to 3.875	0.635	0.025	0.81	0.032	1.52	0.060
25–100	3.875–15.5	1.02	0.040	1.27	0.050	2.03	0.080
100–500	15.5–77.5	1.52	0.060	1.78	0.070	2.54	0.100
Above 500	Above 77.5	2.03	0.080	2.54	0.100	3.05	0.120

(a) Area of a single main plane

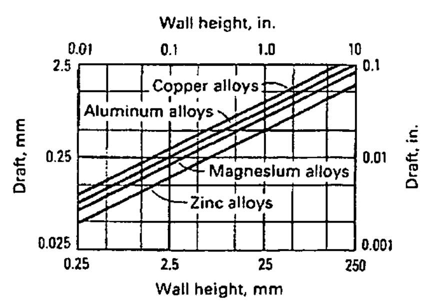
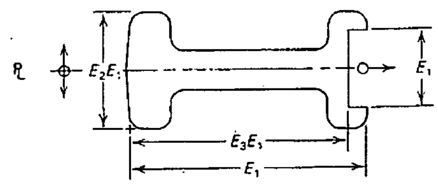


Fig. 4 Minimum drafts required for inside walls of die castings made from four different types of casting alloys

Table 5 Recommended additional tolerances for die castings produced in dies with moving parts

Tolerances in this table should be used in conjunction with those listed in Table 3. See also Table 4.



The tolerance on dimensions such as E_3E_1 will be the value shown in the table plus the linear tolerance from Table 3. The value chosen from the table depends on the projected area of the portion of the die casting formed by the moving die part perpendicular to the direction of movement.

Projected area of die casting, in.^{2}	Additional tolerance(a) (in.) for: Zinc alloy castings	Aluminum and magnesium alloy castings	Copper alloy castings
Up to 10	±0.004	±0.005	±0.010
10–20	±0.006	±0.008	...
20–50	±0.008	±0.012	...
50–100	±0.012	±0.015	...
100–200	±0.016	±0.020	...
200–350	±0.020	±0.025	...
350–600	±0.025	±0.030	...
600–1000	±0.030	±0.035	...

(a) Example: An aluminum alloy casting formed using a moving die part and having a projected area of 75 in.^{2} would have a tolerance of ±0.025 in. on a critical 5.000 in. dimension E_3E_1 (that is, ±0.015 in. for 75 in.^{2} plus ±0.010 in. on linear dimensions). See Table 3. Source: Ref 3

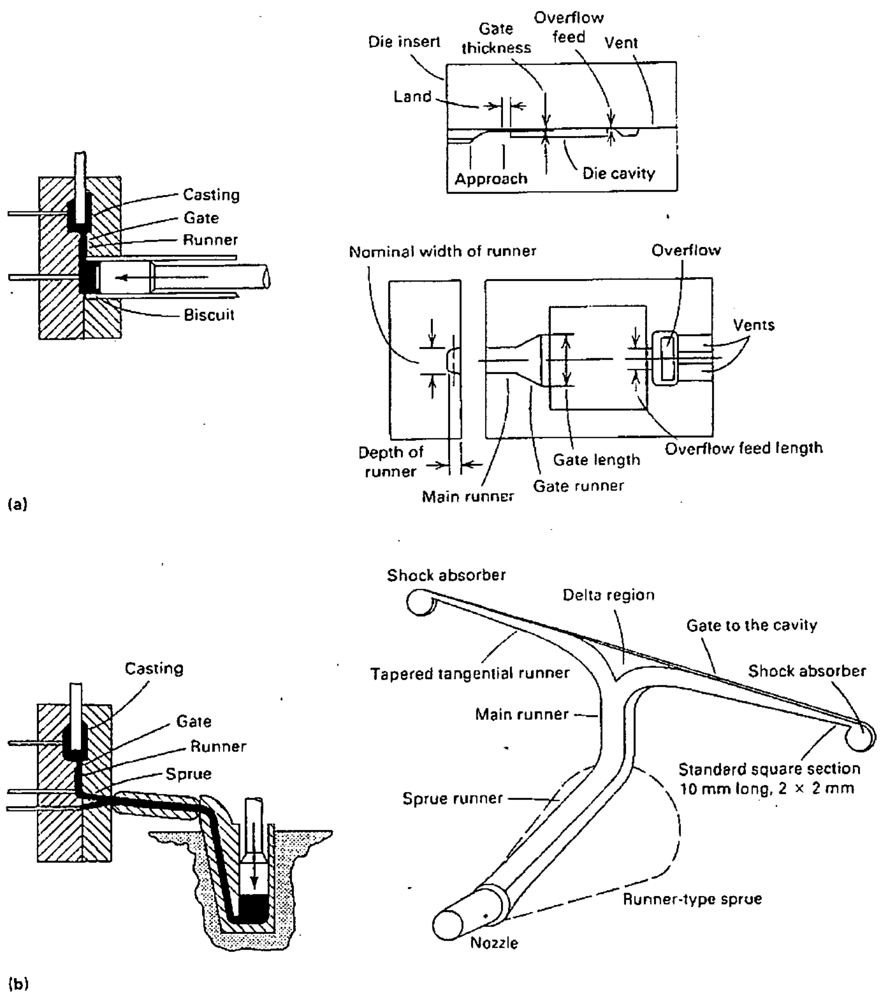


Fig. 5 Schematics showing gating systems for cold chamber (a) and hot chamber (b) die casting machines

of entry, which are directly affected by pa shape and secondary operations.

One of the first analysis methods was th ADCI/DCRF Nomograph (Fig. 7), whic solves geometric relationships for the bul flow design. The selection of a fill time fc the casting is based on experience and e) periment. The limited selection of plung(diameters for a given machine restricts tł design. The cold chamber process links tł volume of metal to plunger diameter b filling the shot sleeve about two-thirds ful The nomograph is used to develop a r quired volume fill rate Q.

It has recently been recognized that tł ability of the casting machine to provide th metal volume flow, while keeping the di(closed during injection, must be considere(The tool that has been developed for th purpose is called the P-Q^2 diagram (Fig. 8 It can be shown that the pressure P on tł metal and hydraulic system is proportion to the square of the injection velocity ar therefore the volume flow rate Q. The lir with the negative slope is the machine cha acteristic line. The characteristic line mov(as shown with changes in hydraulic pre sure, shot valve throttling, and plunger d ameter. The line that starts at the origin (the graph is a measured relationship (pressure to flow rate for the particular cas ing and gate being cast. The effect of adjus ing the gate area is shown.

Optimization of these various paramete for the casting and machine provides tł process engineer with a powerful tool f(process definition and debugging. A numb(of microcomputer programs are available

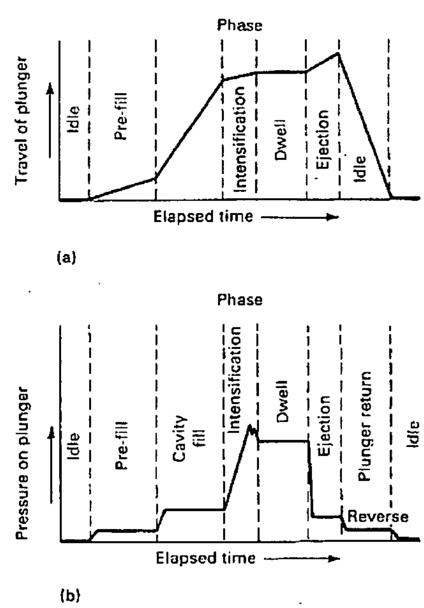


Fig. 6 Curves for plunger travel versus time (a) a plunger pressure versus time (b) indicati the various phases of a shot

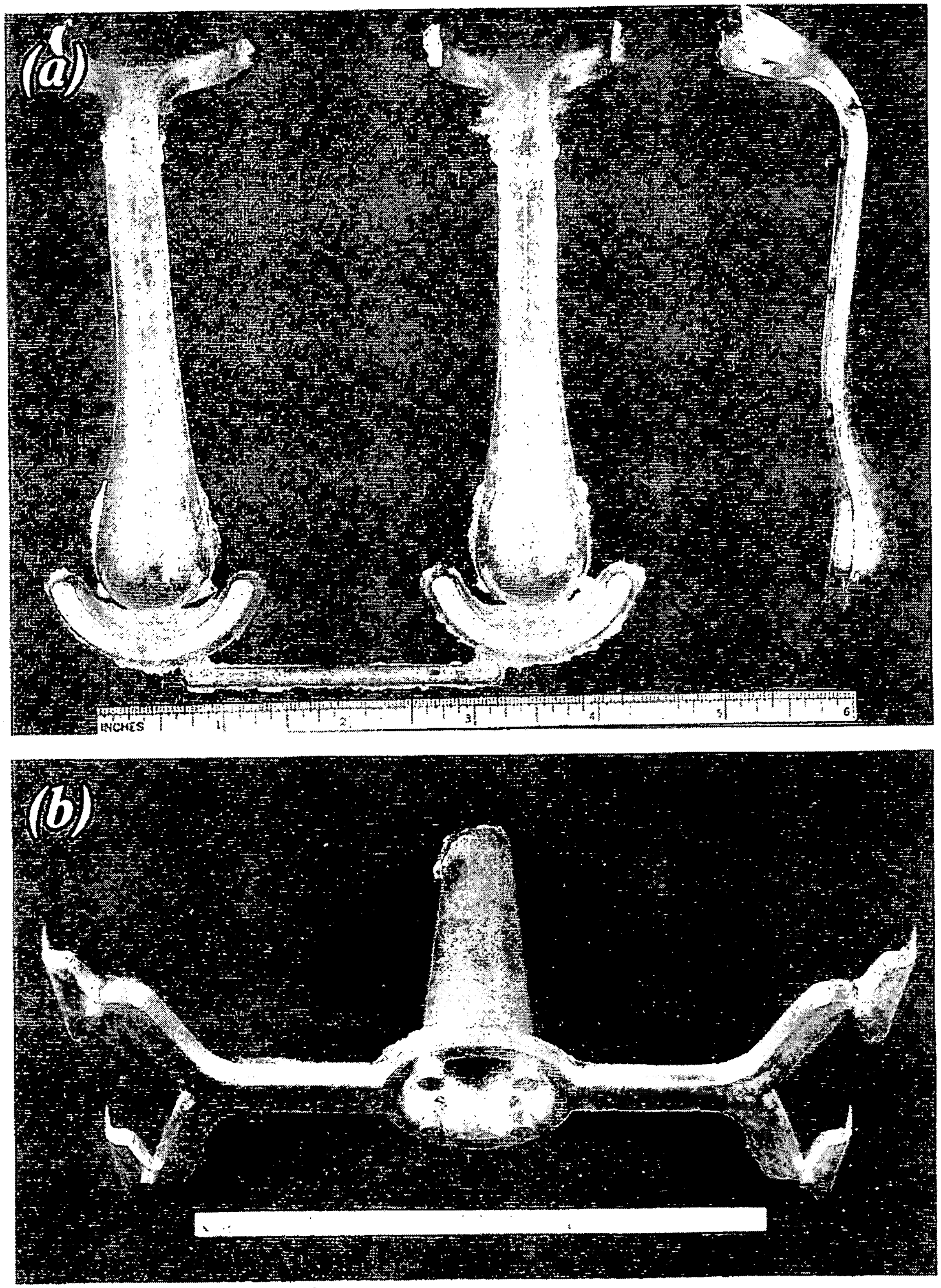


Figure 6 – Views of (a) the as-cast handle and (b) the feed system.